

WHAT IS CLAIMED IS:

1. A magnetoresistive element, comprising:

5 a magnetoresistive film comprising a magnetization  
pinned layer, a magnetization free layer, and a  
nonmagnetic intermediate layer, a magnetization  
direction of the magnetization pinned layer  
substantially fixed in an external magnetic field,  
a magnetization direction of the magnetization free  
layer configured to change in the external magnetic  
10 field, the nonmagnetic intermediate layer formed  
between the magnetization pinned layer and the  
magnetization free layer and having a stacked structure  
of a first non-metallic intermediate layer/a metal  
intermediate layer/a second non-metallic intermediate  
15 layer; and

a pair of electrodes coupled to the  
magnetoresistive film and configured to provide  
a current in a direction substantially perpendicular to  
a surface of the magnetoresistive film.

20 2. The magnetoresistive element according to  
claim 1, wherein the metal intermediate layer has  
a thickness in a range of 0.5 nm to 20 nm.

25 3. The magnetoresistive element according to  
claim 1, wherein the first non-metallic intermediate  
layer is formed adjacent to the magnetization free  
layer, and the magnetoresistive element further  
comprising a first interface metal layer formed between

the magnetization free layer and the first non-metallic intermediate layer.

4. The magnetoresistive element according to claim 1, wherein the second non-metallic intermediate layer is formed adjacent to the magnetization pinned layer, and the magnetoresistive element further comprising a second interface metal layer formed between the magnetization pinned layer and the second non-metallic intermediate layer.

5. The magnetoresistive element according to claim 1, wherein the metal intermediate layer contains at least one metal selected from the group consisting of Al, Cu, Au, Ag, Pt, Pd, Ir and Os.

6. The magnetoresistive element according to claim 3, wherein the first interface metal layer contains at least one metal selected from the group consisting of Al, Cu, Au, Ag, Pt, Pd, Ir and Os.

7. The magnetoresistive element according to claim 4, wherein the second interface metal layer contains at least one metal selected from the group consisting of Al, Cu, Au, Ag, Pt, Pd, Ir and Os.

8. The magnetoresistive element according to claim 1, wherein each of the first and second non-metallic intermediate layers has a structure in which a columnar conductive phase is formed in an insulating phase formed of an oxide, an oxynitride or a nitride.

9. The magnetoresistive element according to claim 8, wherein the insulating phase contains an oxide, an oxynitride or a nitride of at least one element selected from the group consisting of B, Si, Ge, Ta, W, Nb, Al, Mo, P, V, As, Sb, Zr, Ti, Zn, Pb, Th, Be, Cd, Sc, La, Y, Pr, Cr, Sn, Ga, In, Rh, Pd, Mg, Li, Ba, Ca, Sr, Mn, Fe, Co, Ni, Rb and a rare earth metal, and the conductive phase contains an element selected from the group consisting of Cu, Au, Ag, Pt, Pd, Ir and Os.

10. The magnetoresistive element according to claim 8, wherein the columnar conductive phase has a size of 10 nm or less.

11. The magnetoresistive element according to claim 8, wherein an area ratio of the conductive phase in each of the surfaces of the first and second non-metallic intermediate layers is in a range of 1% to 20%.

12. The magnetoresistive element according to claim 8, wherein the conductive phases in the first and second non-metallic intermediate layers and the metal intermediate layer are formed of the same material.

13. The magnetoresistive element according to claim 8, wherein the conductive phases in the first and second non-metallic intermediate layers and the metal intermediate layer are formed of different materials.

14. The magnetoresistive element according to

claim 1, further comprising an antiferromagnetic layer formed in contact with the magnetization pinned layer.

15. A magnetic reproducing head, comprising:

5 a magnetoresistive film comprising a magnetization pinned layer, a magnetization free layer, and a nonmagnetic intermediate layer, a magnetization direction of the magnetization pinned layer substantially fixed in an external magnetic field, a magnetization direction of the magnetization free layer  
10 configured to change in the external magnetic field, the nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer and having a stacked structure of a first non-metallic intermediate layer/a metal intermediate  
15 layer/a second non-metallic intermediate layer; and  
a pair of electrodes coupled to the magnetoresistive film and configured to provide a current in a direction substantially perpendicular to a surface of the magnetoresistive film.

20 16. The magnetic reproducing head according to claim 15, wherein the first non-metallic intermediate layer is formed adjacent to the magnetization free layer, and the magnetoresistive element further comprising a first interface metal layer formed between  
25 the magnetization free layer and the first non-metallic intermediate layer.

17. The magnetic reproducing head according to

claim 15, wherein the second non-metallic intermediate layer is formed adjacent to the magnetization pinned layer, and the magnetoresistive element further comprising a second interface metal layer formed  
5 between the magnetization pinned layer and the second non-metallic intermediate layer.

18. A magnetic reproducing apparatus, comprising:  
a magnetic reproducing head, the magnetic reproducing head comprising a magnetoresistive  
10 film comprising a magnetization pinned layer, a magnetization free layer, and a nonmagnetic intermediate layer, a magnetization direction of the magnetization pinned layer substantially fixed in an external magnetic field, a magnetization direction  
15 of the magnetization free layer configured to change in the external magnetic field, the nonmagnetic intermediate layer formed between the magnetization pinned layer and the magnetization free layer and having a stacked structure of a first non-metallic  
20 intermediate layer/a metal intermediate layer/a second non-metallic intermediate layer; and

a pair of electrodes coupled to the magnetoresistive film and configured to provide a current in a direction substantially perpendicular to  
25 a surface of the magnetoresistive film.

19. The magnetic reproducing apparatus according to claim 18, wherein the first non-metallic

intermediate layer is formed adjacent to the magnetization free layer, and the magnetoresistive element further comprising a first interface metal layer formed between the magnetization free layer and  
5 the first non-metallic intermediate layer.

20. The magnetic reproducing apparatus according to claim 1, wherein the second non-metallic intermediate layer is formed adjacent to the magnetization pinned layer, and the magnetoresistive  
10 element further comprising a second interface metal layer formed between the magnetization pinned layer and the second non-metallic intermediate layer.